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J. Scott Taylor

*University of Wisconsin*

Kevin E. Church

*Advanced Telemetry Systems, Inc.*

Donald H. Rusch

*University of Wisconsin*

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# HABITAT AND WEATHER EFFECTS ON NORTHERN BOBWHITE BROOD MOVEMENTS

J. Scott Taylor<sup>1</sup>

Department of Wildlife Ecology, University of Wisconsin, Madison, WI 53706

Kevin E. Church

Advanced Telemetry Systems, Inc., 470 First Avenue North, Box 398, Isanti, MN 55040

Donald H. Rusch<sup>2</sup>

Wisconsin Cooperative Wildlife Research Unit, 226 Russell Labs, University of Wisconsin, Madison, WI 53706

## ABSTRACT

We observed radio-marked northern bobwhite (*Colinus virginianus*) broods (adults with chicks  $\leq 21$  days old;  $n = 12$ ) in Kansas during 1991–94 to test effects of weather (temperature and precipitation) and macrohabitat (composition, relative diversity, and mean distance to grassland) variables on brood home range size and daily movements at large (28.5 km<sup>2</sup>), intermediate (3.14 km<sup>2</sup>), and small (about 0.14 km<sup>2</sup>) spatial scales surrounding habitats available for broods. Principal component analyses followed by stepwise multiple linear regression indicated neither weather nor habitat influenced ( $P \geq 0.1$ ) home range size at the large and intermediate scales. However, the principal component representing mean distance to grassland and percent cropland within the home range (i.e., at a small scale) was positively related to home range size. Neither temperature nor habitat influenced daily distance of movements. We concluded that brood mobility was independent of landscape-scale features, but that habitat management at smaller spatial scales could influence movements. To create optimal habitat for bobwhite, managers should consider relationships among habitat attributes and the movement of individuals, including the spatial scales at which these relationships are most important.

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## INTRODUCTION

Chick survival can influence annual recruitment, and hence fall population size, in some galliforms (Redfield 1975, Potts 1986, Hill and Robertson 1988). Therefore, increasing chick survival by improving brood habitat has been a high priority for the management of these species (Potts 1986, Hill and Robertson 1988). The efficacy of similar strategies to increase northern bobwhite productivity is unknown because few estimates of chick survival, let alone habitat attributes affecting survival, are available (DeVos and Mueller 1993, Taylor et al. 1999). Estimates of chick survival are difficult to obtain because rates of brood abandonment (Suchy and Munkel 1993, Burger et al. 1995), adoption (Burger et al. 1995), and mixing (Taylor 1997) are difficult to estimate. Such factors also make estimated changes in brood size unreliable indicators of chick mortality.

An inverse relationship between chick survival and brood movement has been well demonstrated for gray (*Perdix perdix*) and red-legged partridges (*Alectoris rufa*; Green 1984), ring-necked pheasant (*Phasianus colchicus*; Warner (1984), Hill and Robertson (1988), and willow ptarmigan (*Lagopus lagopus*; Er-

ikstad 1985), and hypothesized for greater prairie-chicken (*Tympanuchus cupido*; Svedarsky 1988) and northern bobwhite (DeVos and Mueller 1993). Broods increase movements in response to low densities of insects and other food items (Green 1984) and contact with predators (Sonerud 1985, Svedarsky 1988), both of which may directly influence chick survival. If these relationships hold for bobwhites and are mediated by vegetation or other land cover attributes, those attributes associated with small relative brood movements and high chick survival could be used to define and identify high quality brood habitat. However, factors unrelated to habitat (e.g., temperature and precipitation) can also affect brood movements (Green 1984), so their influence must also be considered when using movements to make inferences about habitat quality.

To examine habitat-brood movement relationships, we measured home ranges and minimum daily distances traveled by radio-marked northern bobwhite broods in Kansas during 1991–1994, and identified macrohabitat and weather variables that could be potentially associated with the extent of movements. Habitat composition and configuration effects on bobwhite brood movements at landscape (Taylor and Guthery 1994a) and smaller (Lehmann 1984) spatial scales have been hypothesized; therefore, we tested movement-habitat associations at landscape (28.5 km<sup>2</sup>), intermediate (3.14 km<sup>2</sup>), and small (0.14 km<sup>2</sup>) scales.

<sup>1</sup> Present address: Advanced Telemetry Systems, Inc., 470 First Avenue North, Box 398, Isanti, MN 55040.

<sup>2</sup> Deceased.

## STUDY AREAS

We studied bobwhite on 2, 28.5-km<sup>2</sup> areas south of Emporia in Lyon County, Kansas. The regional climate is mid-continental; the average maximum daily temperature during summer is 31°C (Neill 1981). Mean annual precipitation is 88 cm, 73% of which falls during April–September (Neill 1981).

The rangeland study area (RSA) consisted of 72% native tallgrass rangeland. Other habitat types included cropland (8%), native grass hayfield (8%), and fallow (9%), 62% of which was warm season native grass stands established under Conservation Reserve Program (CRP) guidelines. Woodland (generally limited to drainageways) and wetland combined to comprise <3% of the area. Dominant herbaceous plant species in all cover types except row crop, woodland, and wetland included big bluestem (*Andropogon gerardii*), little bluestem (*Schizachyrium scoparium*), Indiangrass (*Sorghastrum nutans*), and switchgrass (*Panicum virgatum*). Rangeland was seasonally grazed from mid-April through September–October and burned (usually during early April) every 1–4 years.

The cropland study area (CSA) was 24 km east of the RSA. Habitat types included row (grain sorghum, soybean, and corn) and cereal (primarily wheat) cropland (49% of the area), native grass hayfield (19%), native rangeland (16%), and fallow (14%), 52% of which was smooth brome (*Bromus inermis*) and native grass CRP fields. Woodland habitats were located along drainageways and as hedgerows [predominantly osage orange (*Maclura pomifera*)], along field borders. When combined with wetlands these habitats comprised <3% of the study area.

## METHODS

### Telemetry

During March–August 1991–1994, we captured bobwhites on the RSA and CSA using baited funnel traps (Stoddard 1931), decoy traps (Smith et al. 1998), and nightlighting techniques modified from Labisky (1968). We fitted each captured bird with a numbered aluminum leg band and a 6-g (about 3% of body mass) radiotransmitter. Transmitters were backpack-mounted in 1991–1993, and either backpack- or necklace-mounted in 1994. We located each radio-marked quail 4–7 times per week on foot by homing (White and Garrott 1990, Stauffer 1993), and consecutive identical location estimates identified incubating birds. Movements by broods resulting from these nesting attempts were used in subsequent analyses. Direct observations and the presence of chick feces at roost sites were used to determine whether radio-marked adults maintained association with chicks.

We located brood-tending adults twice daily, with >5 hours separating locations, until chicks reached 21 days of age. We recorded the hectare each location was within based on aerial photo-derived cover type maps (scale 1:9500) overlaid with a Universal Transverse Mercator coordinate grid. Brood home range sizes

were estimated using the 95% isopleth of a kernel estimator (Worton 1989) with a grid size of 20 × 20. Home ranges were calculated only for adults with broods during the entire 21-day period posthatch.

In 1994, we also measured daily minimum distances traveled by broods. Using protocols similar to Taylor and Guthery (1994a), broods were located 5 times within a 24-hr period (including ≥1 roost location), and the sum of the distances between consecutive locations determined daily distance traveled. We collected these data once when chicks were 1–14 days old (prefledging), and again when they were 15–28 days old (postfledging).

### Habitat Analyses

We measured macrohabitat composition, relative diversity, and mean distance to grassland (MDG) at several spatial scales surrounding broods. For relationships with home range sizes, we measured habitat attributes within home ranges (small scale; mean area = 0.14 km<sup>2</sup>), within 1 km-radius circles centered at the geometric center of home ranges (intermediate scale; area = 3.14 km<sup>2</sup>), and within study areas (large scale; area = 28.5 km<sup>2</sup>). For relationships with daily movements, habitat at the small scale was measured within 418-m-diameter circles (418 m = mean daily distance traveled by broods; see below) centered at the mean of the 5 location coordinates in each daily series. Habitat at intermediate and large scales was defined the same as for relationships with home ranges.

To measure habitat parameters, we produced a computerized (raster) image of habitat present within each study area with a geographic information system (WSEAS, John Cary, Department of Wildlife Ecology, University of Wisconsin-Madison). Each pixel within these coverages represented a 10 × 10 m area and was assigned its appropriate habitat type (rangeland, hayfield, fallow, cropland, woodland, or wetland). Habitat compositions within defined areas (e.g., study areas or home ranges) were determined by adding the number of pixels assigned to each habitat type within the area and then multiplying each sum by the area of a pixel (0.01 ha). Relative diversity (i.e., evenness; Zar 1984: 34) of habitat compositions was also calculated. Finally, as a measure of grassland distribution, MDG (Brady et al. 1993) within defined areas was calculated by averaging the distances from each pixel within the area to the nearest pixel containing a grass-dominated habitat type (rangeland, hayland, or fallow), with grassland pixels assigned a distance of zero. Broods with >30% of their surrounding habitat at small or intermediate scales occurring outside the study area (i.e., unmapped) were excluded from analyses.

We also monitored temperature and precipitation during the 21-day rearing period for each brood. For comparison with home range size, the mean daily high and low temperatures (°C) and total precipitation (cm) (National Oceanographic and Atmospheric Administration 1991–1994) during each rearing period were calculated. For comparison with daily movements, the

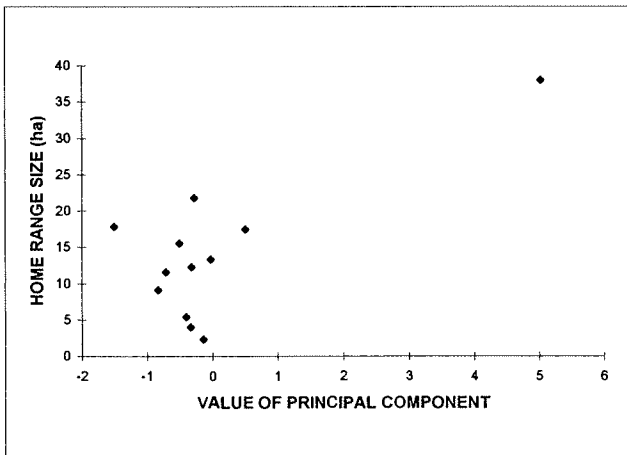


Fig. 1. Home range sizes of northern bobwhite broods ( $n = 12$ ) in Kansas, 1991–94, versus a principal component derived from habitat variables measured within home ranges. The principal component had significant positive correlations with the mean distance to grassland and percent cropland within home ranges, and was positively associated ( $R^2 = 0.551$ ,  $P = 0.006$ ) with home range size.

daily high and low temperatures and precipitation were recorded.

We used stepwise multiple linear regression (Neter and Wasserman 1974) to detect relationships between movements and habitat or weather variables. Principal component analyses (Harris 1975) were used to reduce the effects of multicollinearity among weather variables, as well as among habitat variables in intermediate and small scales. The fewest components at each scale that cumulatively accounted for >80% of the standardized variance were included in the regression model as independent variables. Separate regression analyses were performed for home range size, daily minimum distance traveled by pre fledging broods, and daily distance traveled by post fledging broods as dependent variables. Selection criteria for independent variable entry and removal from stepwise models was  $P \leq 0.1$ .

Table 1. Relationships between habitat variables within home ranges of northern bobwhite broods ( $n = 12$ ) in Kansas, 1991–94, and a principal component derived from those variables that was positively associated with brood home range size. Absolute values of eigenvectors represent the relative contribution of each habitat variable to the value of the principal component.

Habitat variable	Eigenvector	Linear correlation with principal component	
		$r$	$P$
Mean distance to grassland	0.641	0.97	<0.001
Cropland (%)	0.633	0.96	<0.001
Rangeland (%)	-0.255	-0.39	0.205
Wetland (%)	-0.233	-0.38	0.222
Hayland (%)	-0.208	-0.33	0.294
Relative diversity	-0.112	-0.18	0.569
Fallow (%)	-0.106	-0.14	0.662
Woodland (%)	-0.033	-0.06	0.845

## RESULTS

### Home Range

Radio-marked adults reared 14 broods (8 on the CSA, 6 on the RSA), and sufficient habitat was mapped surrounding 12 (6 on each study area) for inclusion in analyses of habitat-movement relationships. Home ranges were similar for brood-rearing adults wearing different transmitter types ( $F = 2.41$ , 1 df,  $P = 0.159$ ) and between study areas ( $F = 0.87$ , 1 df,  $P = 0.530$ ); therefore, we pooled observations across these variables for subsequent analyses. Mean ( $\pm$  SE) home range size was  $14 \pm 3$  ha.

We reduced the 3 weather variables to 1 principal component, the 8 intermediate scale habitat variables to 3 components, and the 8 small scale habitat variables to 4 components. Of these, only 1 small scale habitat component was associated ( $\beta_1 = 0.04$ ,  $R^2 = 0.551$ ,  $P = 0.006$ ; Figure 1) with home range size. The habitat variables most heavily represented by this component (Table 1) were mean distance to grassland and percent cropland within the home range, both of which were positively associated with the component.

### Minimum Daily Distance Traveled

Nine broods (6 on the CSA, 3 on the RSA) provided both pre fledge and post fledge movement estimates, 2 (CSA) provided only pre fledge estimates, and 1 (CSA) provided only a post fledge estimate. Movements were similar during both periods between study areas ( $F = 1.02$ , 1 df,  $P = 0.347$ , and  $F = 0.07$ , 1 df,  $P = 0.799$ , respectively) and transmitter types ( $F = 0.21$ , 1 df,  $P = 0.659$ , and  $F = 1.09$ , 1 df,  $P = 0.337$ , respectively); therefore, estimates were pooled across these variables.

Mean daily distance traveled was  $337 \pm 54$  m and  $503 \pm 60$  m for pre fledging and post fledging broods, respectively. For broods with estimates during both periods, movements were similar (paired  $t = 1.40$ , 8 df,  $P = 0.199$ ) between periods, and the overall mean of daily movements was  $418 \pm 44$  m. However, because estimates during the 2 periods were not independent, we retained the period classification for subsequent analyses.

Precipitation occurred only 1 day during daily movement measurements, so we removed this variable from analyses. The 2 remaining weather variables (maximum and minimum temperatures) were highly correlated ( $r = 0.92$ ,  $P < 0.001$ ), so we used only maximum temperature in the regressions. Further, we reduced the 8 intermediate scale habitat variables to 2 principal components, and the 8 small scale habitat variables to 4 components. Regressions indicated neither habitat components nor temperature were associated ( $P > 0.1$ ) with daily distance traveled by either pre fledging or post fledging broods.

## DISCUSSION

Taylor and Guthery (1994a) reported mean daily movements of broods in southern Texas rangeland

(277 and 589 m for pre fledging and post fledging broods, respectively) that were similar to those we observed (337 and 503 m). Our mean home range size for 3-week-old broods (14 ha) is larger than data reported by DeVos and Mueller (1993) for 2-week-old (6.5 ha) and 4-week-old (10.0 ha) broods in northern Florida. However, these estimates are not directly comparable because different methods (kernel vs. minimum convex polygon) were used to determine range sizes.

Daily distance traveled did not vary with brood age. This is similar to the observations of Green (1984) for gray and red-legged partridges; however, investigators elsewhere have found changes in brood movements with age in bobwhite (Taylor and Guthery 1994a) and other galliforms (Warner 1979, Bergerud and Gratson 1988). Based on the apparent disparity between mean movements, our failure to detect a difference between pre fledging ( $\bar{x} = 337$  m) and post fledging ( $\bar{x} = 503$  m) movements may have been due to our limited sample size ( $n = 9$ ) and the resulting low power ( $1 - \beta = 0.341$  at  $\alpha = 0.1$ ) of our comparison.

We failed to detect temperature effects on brood home range size, or on daily movements. However, nest success was lower during wet than dry years (Taylor 1997), so relatively few broods were observed during periods in which precipitation and temperature effects may have been most extreme. Galliform chicks generally require more brooding during cool, wet periods. Thus their activity is restricted under such conditions (Green 1984, Bergerud and Gratson 1988). Insects also may become less active and presumably less available to chicks during periods of precipitation (Hill and Robertson 1988). However, cool, wet weather does not necessarily lead to low chick survival or overall productivity for bobwhite in the Midwest (Roseberry and Klimstra 1984) or other galliforms (Potts 1986).

Brood home ranges tended to be larger when they contained more cropland and greater mean distance to grassland values. However, 1 brood seemed to have a large influence on this relationship (Figure 1). This CSA brood had a 38-ha home range (the next largest observed home range was 22 ha) which contained 88% cropland (the next largest amount of cropland within a home range was 24%). The brood hatched on 26 July 1994, and was unique in that it primarily used linear grassland and woodland patches in the midst of large soybean and sorghum fields. Although the habitats used by this brood were not typical of those used by other broods we observed, they may resemble those available to bobwhite in more intensively cultivated regions (e.g., the highest apparent breeding bobwhite densities occurred in areas with only 12–25% grassland in Illinois; Roseberry and Sudkamp (1998).

If the relationships observed for other galliforms such as: (1) chick survival and movements are negatively related (Green 1984, Erikstad 1985, Hill and Robertson 1988), and; (2) brood movements are negatively related to habitat quality (Southwood and Cross 1969, Erikstad 1985) are true for bobwhites, then

broods with less cropland and smaller mean distance to grassland within their home ranges had a lower risk of chick mortality. Whether grassland habitat types provided less exposure to predators (Sonerud 1985), greater availability of insects and other food items (Southwood and Cross 1969, Erikstad 1985), or greater microhabitat variability (Taylor and Guthery 1994b) relative to cropland is unknown; each has been experimentally or hypothetically related to brood mobility or survival. Until relationships among these factors and macrohabitat characteristics are understood, the link between bobwhite brood movements and the fitness value of macrohabitat attributes is speculative at best.

The associations we observed between movements and habitat at a small spatial scale did not persist at intermediate and large scales. This did not support the hypothesis that bobwhite brood movements are dependent on landscape-scale habitat features (Taylor and Guthery 1994a). However, whereas the CSA was much more extensively cropped than the RSA, it still contained 49% grassland (i.e., rangeland, hayland, and fallow). This is likely a higher percentage than exists in many other locations within the bobwhite range, and may not have been sufficiently different from the RSA (89% grassland) for landscape effects to have been evident. Regardless, our lack of replication at the landscape scale made our study area comparison exploratory rather than experimental, thus our results should be viewed in this context.

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